DTU Library

Dispersion and nonlinearity tolerance of modulation formats for 160 Gb/s systems

Zhenbo, Xu; Peucheret, Christophe; Siahlo, Andrei; Rottwitt, Karsten; Jeppesen, Palle

Published in:
Technical Digest Conference on Lasers and Electro-Optics 2004

Publication date:
2004

Document Version
Publisher's PDF, also known as Version of record

Dispersion and nonlinearity tolerance of modulation formats for 160 Gb/s systems

Zhenbo Xu, C. Peucheret, A. I. Siahlo, K. Rottwitt, P. Jeppesen
Research Center COM, Technical University of Denmark, Kgs. Lyngby, DK-2800, Denmark
Email: xuz@com.dtu.dk

Abstract: We compare the RZ-DQPSK modulation format in 160 Gb/s single channel systems with RZ, CSRZ, RZ-DPSK and CSRZ-DPSK for the first time. We find that RZ-DQPSK offers nearly three time better dispersion tolerance than CSRZ-DPSK.

OCIS codes: (060.2330) Fiber optics communications; (060.4080) Modulation

Introduction

Recent publications on high bit rate systems above 40 Gb/s emphasize various new modulation formats [1]. New modulation formats that offer large dispersion and nonlinear tolerance pave the way to greatly increased system capacity and transmission distance [2,3]. In this paper, we compare various modulation formats for 160 Gb/s single channel systems using numerical simulation. We find the return-to-zero differential quadrature phase shift keying (RZ-DQPSK) format to be much more promising than other formats such as RZ, CSRZ, RZ-DPSK and CSRZ-DPSK.

Simulation results

Fig. 1 illustrates the generation methods for the various modulation formats. To obtain the RZ with duty cycle of 50% and CSRZ modulation formats, the CW light is modulated by a Mach-Zenhder modulator using proper bias and voltage swing. The DPSK signal is generated by a phase modulator; subsequently it can be carved to RZ or CSRZ pulse shape. A DQPSK signal needs two 80 Gb/s DPSK encoders with uncorrelated data sequences accompanied by $\pi/2$ phase shift between them [4]. In the receiver, following an EDFA with 4 dB noise figure, a one-bit delay MZI is needed to demodulate the family of DPSK signals. For DQPSK, two interferometers are needed to decode the two tributary data sequences. Balanced detection is used for the family of DPSK signals. The transmission span is composed of 80 km SMF and 12 km DCF with complete dispersion and slope compensation.

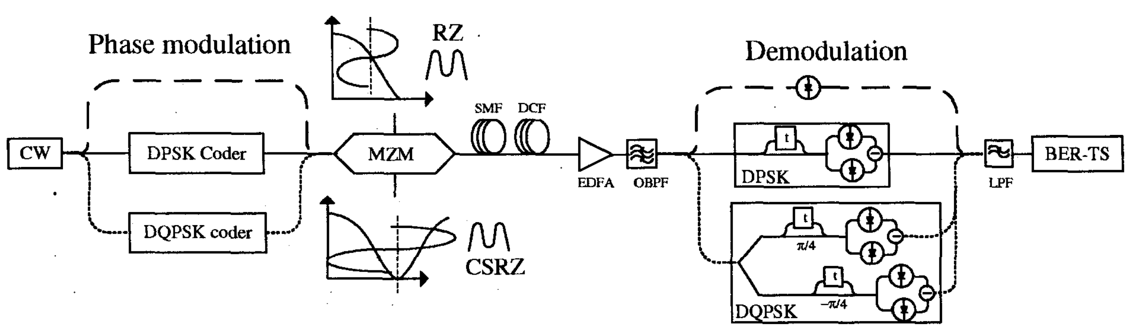

Fig. 1 Setup for generation, transmission and demodulation of the different modulation formats
OBPF: optical bandpass filter, LPF: electrical low pass filter

For each modulation format, the receiver electrical and optical bandwidths are optimized based on the maximum back-to-back (B2B) eye opening normalised to the eye opening at the transmitter output [$10\log_{10}$(eye-from-transmitter/B2B-eye-opening)]. Fig. 2 shows the normalised eye-opening as a function of residual dispersion obtained by varying the DCF length, for a span average input power of 0 dBm. The dispersion tolerance for 1 dB eye opening penalty is equal to 1.4, 2.4, 1.5 and 2.2 ps/nm for RZ, CSRZ, RZ-DPSK and CSRZ-DPSK. However, the most significant improvement is offered by RZ-DQPSK, for which the dispersion tolerance exceeds 6.2 ps/nm.

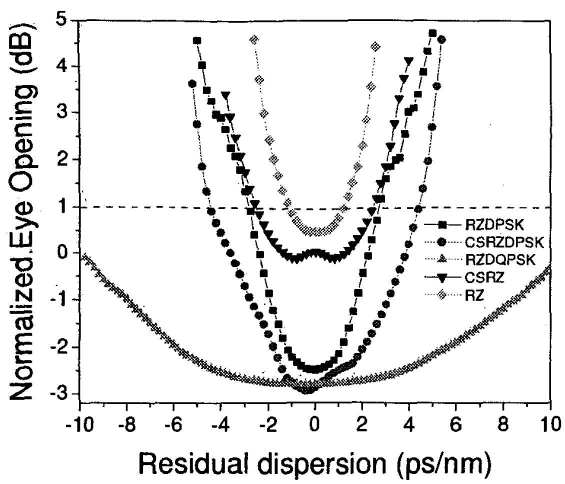

Fig. 2. Normalized eye opening vs. span residual dispersion for the five modulation formats.

Fig. 3 shows the tolerance to launched power for the five modulation formats. It can be seen that RZ-DQPSK not only offers improved dispersion tolerance, but also results in resilience to self-phase modulation similar to that of CSRZ and CSRZ-DPSK.

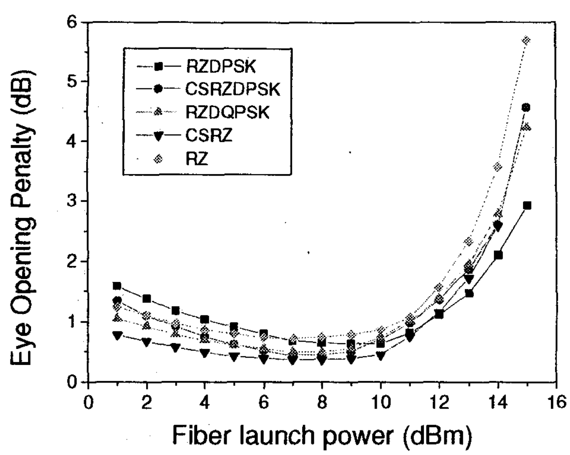

Fig. 3. Eye opening penalty vs. span launch power for the five modulation formats.

Conclusion

We find that for single channel systems, the RZ-DQPSK format has much larger dispersion tolerance than the other modulation formats, and similar sensitivity to fiber nonlinearity compared to other DPSK related formats. Furthermore, its generation method is more feasible for practical 160 Gb/s systems as it only requires components compatible with 80 Gb/s, and it is more suitable for spectrally efficient WDM systems than the other formats.

Reference

1. A. Gnauck, *et al*, "40-Gb/s RZ-Differential phase shift keyed transmission", ThE1, OFC 2003.
2. B. Zhu, *et al*, "6.4-Tb/s(160×42.7 Gb/s) transmission with 0.8 bit/s/Hz spectral efficiency over 32×100 km of fiber using CSRZ-DPSK format", PD19-1, OFC 2003.
3. A. H. Gnauck, *et al*, "1-Tb/s(6×170.6 Gb/s) transmission over 2000 km NZDF using OTDM and RZ-DPSK format", Photon. Technol. Lett. **15**, 1618-1620 (2003).
4. O. Vassilieva, *et al*, "Non-linear tolerant and spectral efficient 86 Bb/s RZ-DQPSK format for a system upgrade", ThE7, OFC 2003